BEC of Two Photons and Higgs Physics

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Abstract

It is well understood that the studies of correlations between produced particles, the effects of coherence and chaoticity, an estimation of particle emitting source size play an important role in high energy physics [1]. We mean the investigation of the space-time extension or even squeezing of particle sources via the multiparticle quantum-statistics correlation. We obtain the two-photon correlation function that can provide the space-time information about the Higgs-boson source in thermal environment and we argue that such an investigation could probe the Higgs-boson mass.

1. The Large Hadron Collider (LHC) at CERN is at the stage to provide particle physicists with treasure of data. These data allowed a precise measurement of many important parameters of modern particle physics in order to test their consistency and to discover the Higgs-boson. At the same time, little is known about Higgs-gauge bosons interplay in particular in theoretical aspects. The effect of Bose-Einstein correlations (BEC) is clear and undeniable part of this theory, complicating the quantum statistical description of multi-lepton final states.

Historically, the BEC measurements have concentrated on pion pairs correlations, however have also been applied to more heavy hadrons, quarks, protons, and even gauge bosons, photons, Z-bosons etc.

It is known that the wave function describing a system of two identical bosons should be symmetric under permutation of these bosons. As a consequence, the four-momentum differences between two bosons will be smaller than in the world where Bose-Einstein statistics would not apply.

Actually, the direct photon BEC can provide information about the space-time distribution of the hot matter prior to freeze-out. However, the BEC with direct (primary) photons is faced with difficulties compared to hadron BEC primarily due to the small yield of photons emitted directly from the hot region just after particle

collisions. The main background of photons is produced by decays of final hadrons or gauge bosons, or even (pseudo)scalar particles.

In Higgs searching program at the LHC, we suppose that two photons are produced mainly through Higgs-boson decay. From the theoretical point of view the decay of Higgs into two photons emerges through the one-loop pattern: the Higgs-boson transferred in pair of a quark and antiquark or vector bosons, or even in scalar particles.

In order to reject most of the hadron background, the reconstructed events in a spectrometer were required to have a deposit energy (level) of greater than the energy well above the minimal energy at which photons emerge from hadrons. Experimentally, the π^0 background constitutes a major difficulty which, however, to some extent, can be taken care of by measuring the photon pair invariant mass.

The two-photon correlations in Higgs physics provide a powerful tool to explore the Higgs-boson mass estimated via the correlation radius which defines the geometrical size of the two-photon source. Hence, the two-photon correlation function is strongly dependent on the space-time properties of the Higgs decays.

In the quark-loop scheme, the non-relativistic bremsstrahlung formula for the current in quark-antiquark interaction for one photon emission (with four-momentum $k = (k^0,\, \vec{k})$) is

$$j^{\lambda}(k) = \frac{i\, e}{m_q\, k^0}\, \vec{p} \cdot \vec{\epsilon}_{\lambda}(k)\, e^{-k^0/\varepsilon_0},$$

where $\vec{p}$ is the difference between the spatial momenta of a quark and antiquark with the mass m_q, $\vec{\epsilon}_{\lambda}(k)$ is the vector of linear polarization of a photon; ε_0 means the phenomenological parameter which depends on the initial energy. For two sources the transition current is

$$J^{\lambda}(k) = \sum_{n=1}^{2} e^{i\, k\, y_n}\, j_n^{\lambda}(k).$$

Index n labels the independent quark-antiquark interactions taking place at different space-time points y_n which are considered to be randomly distributed in the space-time volume of the (photon) source. We suppose the gamma-quanta are created by some random currents (sources) $J_{\mu}(x)$ through the Lagrangian density $L_{int} = -g\, J_{\mu}(x)\, A^{\mu}(x)$. The neutral weak current of (final) charged leptons is $J_{\mu}^{l}(x) = -\bar{g}\, \bar{l}(x)\, \gamma_{\mu}\, l(x)$ with $l : e, \mu, \tau$, for which the problem can be solved exactly. Both the currents $J_{\mu}(x)$ and $J_{\mu}^{l}(x)$ exist in a restricted space-time region and they are chaotically and randomly disturbed by external fields (forces). The restricted domain is characterized by the internal stochastic scale L_{st}, the meaning of which is explained in [2,3].

By studying BEC of identical particles, it is possible to determine the time scale and spatial region over which particles do not have the interactions. Such a surface is called as decoupling one. In fact, for an evolving system such as pp collisions, it is not really a surface, since at each time there is a spread out surface due to fluctuations in the last interactions, and the shape of this surface evolve even in time. The particle source is not approximately constant because of energy-momentum conservation constraint.

Actually, the second order distribution function

$$N_{12}(k_1, k_2) = \langle |J^{\lambda_1}(k_1)\, J^{\lambda_2}(k_2)|^2 \rangle$$

normalized to the product $N_1(k_1) \cdot N_2(k_2)$ with one-particle distribution functions $N_i(k_i) = \langle |J^{\lambda_i}(k_i)|^2 \rangle$ $(i = 1, 2)$ formally defines the probability to find two photons with momenta k_1 and k_2 issued at y_1 and y_2. The crossing momenta has to be taken into account.

In this work, we make an attempt to demonstrate that the problem of properties of the genuine interactions can be explored using experimental data which can be collected at the LHC. These data can be analyzed through the compared measures of some inclusive distributions and final state correlations.

One of the aims of this paper is to carry out the proposal for the experimental measurements of virtual $\gamma^\star \gamma^\star$ pair correlations.

This exploration is theoretically supported by the quantum field theory model approaches [4-9,2,3] at finite temperature, (QFT_β), where one of the main parameters is the temperature of the particle (emitting) source under the random external forces (fields) influence.

We propose that photons do not strongly interact with (produced) medium: they carry information about early stage of reaction. Our pragmatic definition is: photons are produced not from hadronic decays. Any source of real gamma-quanta produces virtual photons with very low mass. If the momentum of the virtual gamma-quantum is sufficiently small, the source strength should be small as well. The real gamma-quantum can be measured from the virtual yield which is observed as low mass of the spectrum for lepton-antilepton pair.

The main channels are the two-photon production $pp \to Higgs \to \gamma^\star \gamma^\star \to 2\mu^- 2\mu^+,\ 2e^- 2e^+,\ e^- e^+ \mu^- \mu^+,\ ...$ in pp collisions. An efficient selection of leptons needs to be performed according to the following criteria. First, all leptons were required to lie in the pseudorapidity range covered by, e.g., the CMS muon system that is, $|\eta| \leq 2.4$. Second, the leptons were required to be unlikely charged in pairs.

The di-lepton channel is especially promising from the experimental point of view, since it is expected that the experimental facilities related for LHC will make

it possible to record muons of energy in the TeV range with a resolution of about a few percent and an efficiency close to 100 %. Moreover, this channel is characterized by a maximum signal-to-background ratio in the energy region being considered.

2. A pair of identical bosons with momenta p_1 and p_2 and the mass m produced incoherently from an extended source will have an enhanced probability $C_2(p_1, p_2) = N_{12}(p_1, p_2)/[N_1(p_1) \cdot N_2(p_2)]$ to be measured in terms of differential cross section σ, where

$$N_{12}(p_1, p_2) = \frac{1}{\sigma} \frac{d^2\sigma}{d\Omega_1\, d\Omega_2}$$

to be found close in 4-momentum space $\Re_4$ when detected simultaneously, as compared to if they are detected separately with

$$N_i(p_i) = \frac{1}{\sigma} \frac{d\sigma}{d\Omega_i}, \quad d\Omega_i = \frac{d^3\vec{p}_i}{(2\pi)^3\, 2E_{p_i}}, \quad E_{p_i} = \sqrt{\vec{p}_i^{\,2} + m^2}, \quad i = 1, 2.$$

In an experiment, one can account the inclusive density $\rho_2(p_1, p_2)$ which describes the distribution of two particles in Ω (the sub-volume of the phase space) irrespective of the presence of any other particles

$$\rho_2(p_1, p_2) = \frac{1}{2!} \frac{1}{n_{events}} \frac{d^2 n_2}{dp_1\, dp_2},$$

where n_2 is the number of particles counted in a phase space domain $(p_1 + dp_1, p_2 + dp_2)$. The multiplicity N normalizations stand as

$$\int_\Omega \rho(p)\, dp = \langle N \rangle,$$

$$\int_\Omega \rho_2(p_1, p_2)\, dp_1\, dp_2 = \langle N(N - \delta_{12}) \rangle,$$

where $\langle N \rangle$ is the averaged number of produced particles. Here, $\delta_{12} = 0$ for different particles, while $\delta_{12} = 1$ in case of identical ones (coming from the same event).

On the other hand, the following relation can be used to retrieve the BEC function $C_2(Q)$:

$$C_2(Q) = \frac{N(Q)}{N^{ref}(Q)}, \tag{1}$$

where $N(Q)$, in general case, is the number of particle pairs (off-shell photons) in BEC pattern with

$$Q = \sqrt{-(p_1 - p_2)_\mu \cdot (p_1 - p_2)^\mu} = \sqrt{M^2 - 4\, m^2}. \tag{2}$$

In definitions (1) and (2), N^{ref} is the number of particle pairs without BEC and $p_{\mu_i} = (\omega_i, \vec{p}_i)$ are four-momenta of produced photons ($i = 1,\ 2$); $M = \sqrt{(p_1 + p_2)^2_\mu}$ is the invariant mass of the pair of photons.

An essential problem in two-particle correlations is the estimation of the reference distribution $N^{ref}(Q)$ in Eq. (1). If there are other correlations beside the Bose-Einstein effect, the distribution $N^{ref}(Q)$ should be replaced by a reference distribution corresponding to the two-particle distribution in a geometry without BEC. Hence, the expression (1) represents the ratio between the number of $\gamma^\star\gamma^\star$ pairs $N(Q)$ in the real world and the reference sample $N^{ref}(Q)$ in the imaginary world. Note, that the reference sample can not be directly observed in an experiment. Different methods are usually applied for the construction of reference samples [1], however all of them have strong restrictions. One of the preferable methods is to construct the reference samples directly from data. The $\gamma^\star\gamma^\star$ BEC can be estimated for each bin of the photon average transverse momentum $p_T = |\vec{p}_{T_1} + \vec{p}_{T_2}|/2$ as the ratio of the distribution of photon pair invariant relative momenta where both photons with transverse momenta $\vec{p}_{T_1}$ and $\vec{p}_{T_2}$ were taken from the same event to the same distribution but with the photons of the pairs taken from different events. For our aim, for the reference sample $N^{ref}(Q)$, it is suitable to use the pairs $\gamma^\star\gamma^\star$ from different (mixed) events.

It is commonly assumed that the maximum of two-particle BEC function $C_2(Q)$ is 2 for $\vec{p}_1 = \vec{p}_2$ if no any distortion and final state interactions are taking into account.

In general, the shape of $C_2(Q)$ is model dependent. The most simple form of Goldhaber-like parameterization for $C_2(Q)$ [10,11] is often used for experimental data fitting.

$$C_2(Q) = C_0 \cdot (1 + \lambda e^{-Q^2 R^2}) \cdot (1 + \varepsilon Q), \tag{3}$$

where C_0 is the normalization factor, λ is the chaoticity strength factor, meaning $\lambda = 1$ for fully incoherent and $\lambda = 0$ for fully coherent sources; the symbol R is often called as the "correlation radius", and assumed to be spherical in this parameterization. The linear term in (3) is supposed to be account within the long-range correlations outside the region of BEC. Note that the distribution of bosons can be either far from isotropic, usually concentrated in some directions, or almost isotropic, and what is important that in both cases the particles are under the random chaotic interactions caused by other fields in the thermal bath. In the parameterization (3) all of these issues are embedded in the random chaoticity parameter λ. To advocate the formula (3) it is assumed:

a. incoherent average over particle source where λ serves to account for:

- partial coherence,
- $\gamma\gamma$ purity;

b. spherical Gaussian density of particle emission cell (with radius R);
c. static source which means no time (energy) dependence.
However, to enlarge the quantum pattern of particle production process and to avoid the static and undistorted character of particle emitter source, we have already suggested to use the $C_2(Q)$ function within QFT_β accompanying by quantum evolution approach in the form [2,3]:

$$C_2(p_1, p_2) \simeq \xi(N) \left\{1 + \lambda_1(\beta)\, e^{-\Delta_{p\Re}} \left[1 + \lambda_2(\beta)\, e^{\Delta_{p\Re}/2}\right]\right\}, \tag{4}$$

where $\exp(-\Delta_{p\Re})$ is the smearing smooth dimensionless generalized function with $\Delta_{p\Re} = (p_1 - p_2)^\mu\, \Re_{\mu\nu}\, (p_1 - p_2)^\nu$. $\Re_{\mu\nu}$ is the nonlocal structure tensor of the space-time size and it defines the domain of emitted photons. $\xi(N)$ depends on the multiplicity N as $\xi(N) = \langle N(N-1)\rangle / \langle N\rangle^2$. The functions $\lambda_1(\beta)$ and $\lambda_2(\beta)$ are the measures of the strength of BEC between two photons: $\lambda_1(\beta) = \gamma(\omega, \beta)/(1+\alpha)^2$, and the correction to the coherence function in the brackets of Eq. (4) is $\lambda_2(\beta) = 2\,\alpha/\sqrt{\gamma(\omega, \beta)}$. The function $\gamma(\omega, \beta)$ calls for the quantum thermal features of BEC pattern and is defined as

$$\gamma(\omega, \beta) \equiv \gamma(n) = \frac{n^2(\bar{\omega})}{n(\omega)\; n(\omega')}, \quad n(\omega) \equiv n(\omega, \beta) = \frac{1}{e^{\omega\beta} - 1}, \quad \bar{\omega} = \frac{\omega + \omega'}{2}, \tag{5}$$

where $n(\omega, \beta)$ is the mean value of quantum numbers for Bose-Einstein statistics particles with the energy ω in the thermal bath with statistical equilibrium at the temperature $T = 1/\beta$. The following condition $\sum_f n_f(\omega, \beta) = N$ is evident, where the discrete index f stands for the one-particle state f.

The important parameter $\alpha(\beta)$ in (4), the measure of chaoticity, summarizes our knowledge of other than space-time characteristics of the particle emitting source, and it varies from 0 to ∞ (see [12] for details).

In terms of time-like R_0, longitudinal R_L and transverse R_T components of the space-time size R_μ, the distribution $\Delta_{p\Re}$ looks like

$$\Delta_{p\Re} \to \Delta_{pR} = (\Delta p^0)^2\, R_0^2 + (\Delta p^L)^2\, R_L^2 + (\Delta p^T)^2\, R_T^2. \tag{6}$$

R_0 in (6) is treated as the measure of the particle emission time, or even it represents the interaction strength of outgoing particles.

Hence, we have introduce a new parameter R_μ, a four-vector, which defines the region of nonvanishing particle density with the space-time extension of the particle emission source. Formula (4) must be understood in the sense that $\exp(-\Delta_{p\Re})$ is a

distribution that in the limit $R \to \infty$ strictly becomes a δ - function. For practical using with ignoring the energy-momentum dependence of α, one has:

$$C_2(Q) \simeq \xi(N) \left\{ 1 + \lambda_1(\beta)\, e^{-Q^2R^2} \left[1 + \lambda_2(\beta)\, e^{+Q^2R^2/2} \right] \right\}. \tag{7}$$

The parameter R in formula (7) is the measure of the space-time overlap between two photons, and the physical meaning of R depends on the fitting of $C_2(Q)$-function. R can be defined through the evaluation of the root-mean-squared momentum Q_{rms} as:

$$Q^2_{rms}(\beta) = \langle \vec{Q}^2 \rangle = \frac{\int_0^\infty d|\vec{Q}|\, \vec{Q}^2 \left[\tilde{C}_2(Q,\beta) - 1 \right]}{\int_0^\infty d|\vec{Q}| \left[\tilde{C}_2(Q,\beta) - 1 \right]}, \quad \tilde{C}_2(Q,\beta) = \frac{C_2(Q,\beta)}{\xi(N)},$$

where R and $Q_{rms}(\beta)$ are related to each other by means of

$$R = R(\beta) = \left[\frac{3}{2} \left(1 + \frac{1}{1 + \frac{1}{4\,\alpha(\beta)} \sqrt{\frac{\gamma(n)}{2}}} \right) \right]^{1/2} \frac{1}{Q_{rms}(\beta)}.$$

We find the following restricted window $\sqrt{3/2} < (R \cdot Q_{rms}(\beta)) < \sqrt{3}$, where the lower bound satisfies to the case $\alpha \to 0$ (no any distortion in the particle production domain), while the upper limit is given by the very strong influence of chaotic external fields (forces), $\alpha \to \infty$. The result is rather stable in the wide range of variation of α.

3. It has been emphasized [2,3] that there are two different scale parameters in the model considered here. One of them is the so-called "correlation radius" R introduced in (3) and also presented in (4). In fact, this R-parameter gives the pure size of the particle emission source without the influence of the distortion and interaction forces coming from other fields. The other (scale) parameter is the scale L_{st} of the production particle domain where the stochastic, chaotic distortion due to environment (the influence of other fields, forces) is enforced. This stochastic scale carries the dependence of the particle mass, the α-coherence degree and what is very important - the temperature T-dependence.

One question arises: how can BEC be used to determine the effective scale L_{st} and, perhaps, the phase transition? We suppose the changes of $\gamma^\star\gamma^\star$ production region and effects yielding the dynamical variables and parameters of BEC due to in-medium distortion.

Consider the finite system (expanding or squeezing) with the flow of two gauge bosons pairs, eg., $B_\mu B_\mu$- pairs. The Hamiltonian is

$$H_0 = \frac{1}{2}\int d^3x \left[\left(\dot{\phi}\right)^2 + |\nabla \vec{B}|^2 + m^2\, B_\mu^2\right]$$

which is asymptotically free in the rest frame of undistorted matter with the field $B_\mu = (\phi, \vec{B})$ having the mass m in general case. This Hamiltonian and commutation relations can possess the exact symmetry. However, the observed states in real physical environment can not be realized in the framework of this symmetry. H_0 has to be added by the Hamiltonian

$$H_{dist} = \frac{g^{\mu\nu}}{2}\int d^3\vec{x}\, d^3\vec{y}\, B_\mu(\vec{x})\delta F_\beta^2(\vec{x}-\vec{y})\, B_\nu(\vec{y}),$$

which is provided by the distortion due to in-medium effect, in particular, because of temperature of the environment. The field $B_\mu(\vec{x})$ propagates in medium with p (momentum) - dependent effective (squeezing) frequency $\omega_\beta = \sqrt{m^2 + \vec{p}^2 - \delta\tilde{F}_\beta^2(p)}$ and, consequently, the mass m_β is related to the undistorted (asymptotic) mass m by $m_\beta = \sqrt{m^2 - \delta\tilde{F}_\beta^2(p)}$. Here, $\delta F_\beta^2(\vec{x})$ is the non-local formfactor leading to the modification of the particle frequency (mass) of undistorted matter. Because of the quadratic form of the Hamiltonian H_{dist} through the asymptotic Bose - operators of annihilation (creation) $a(p)(a^+(p))$ in

$$B_\mu(x) = \int \frac{d^3\vec{p}}{(2\,\pi)^3\,\sqrt{m^2+\vec{p}^2}} \sum_\lambda \epsilon_\mu^\lambda(p)\, a(p)\, e^{-i\,p\,x},$$

one can use the Bogolyubov transformation

$$b_f = u_f\, a_f - v_f\, a_{-f}^+, \quad b_f^+ = u_f^\star\, a_f^+ - v_f^\star\, a_{-f}$$

for new operators of annihilation (creation) $b_f(b_f^+)$ in distorted medium. In some sense, the last operators correspond to thermalized-distorted quasiparticles. The functions u_f and v_f obey the condition $|u_f|^2 - |v_f|^2 = 1$ and can be given in the form $u_f = \cosh\eta_f$, $v_f = \sinh\eta_f$, where η_f has to be even function of index f. For simplicity, we identify f with momentum p, and for squeezing frequency one gets $\eta_p = \ln\omega^2(p)/\omega_\beta^2(p)$. Indeed, the Bogolyubov transformation is equivalent to squeezing procedure.

4. In the Higgs-boson rest frame, there is a kinematical configuration for two pairs of final lepton momenta $(p_l, p_{\bar{l}}^\prime)$ and $(q_l, q_{\bar{l}}^\prime)$: $p_l \simeq p_{\bar{l}}^\prime$ and $q_l \simeq q_{\bar{l}}^\prime$. Thus, the

final state mimics a two-body final state, and if the leptons being the electrons or even muons, the virtual photons with momenta p and p' are nearly on mass-shell, $p^2 \simeq {p'}^2 \simeq 4\, m_l^2$, where m_l is the lepton mass. For the configuration given above, the stochastic scale L_{st} has different behavior depending on T. At lower temperatures we have

$$L_{st} \simeq \left[\frac{\pi^{3/2}\, M_H^2\, e^{2\, m_l/T}}{48\, \alpha(N)\, m_l^{11/2}\, T^{3/2} \left(1 + \frac{15}{16}\frac{T}{m_l}\right)} \right]^{\frac{1}{5}}, \tag{8}$$

where the condition $2\, n\, \beta\, m_l > 1$ is taken into account for any integer n; M_H is the mass of the Higgs-boson, m_l stands for the lepton mass.

On the other hand, at higher temperatures, when $T > 2\, n\, m_l$, one has

$$L_{st} \simeq \left[\frac{\pi^2\, M_H^2}{48\, \zeta(3)\, \alpha(N)\, T^3\, m_l^4} \right]^{\frac{1}{5}}, \quad \zeta(3) = \sum_{n=1}^{\infty} n^{-3} = 1.202. \tag{9}$$

In case of two real photons correlation one can use the longitudinal stochastic scale instead of (8) and (9), $L_{st}^{long}(m_l = m_T/2)$, with the average transverse mass $m_T = 0.5(\sqrt{p_{T_1}^2} + \sqrt{p_{T_2}^2})$ in the frame of, e.g., the Longitudinal Center of Mass System (LCMS) [13].

It turns out that the scale L_{st} defines the range of stochastic forces. This effect is given by $\alpha(N)$-coherence degree which can be estimated from the experiment within the function $C_2(Q)$ as Q close to zero, $C_2(0)$, at fixed value of mean multiplicity $\langle N \rangle$:

$$\alpha(N) = \frac{1 + \gamma^{1/2}(n) - \tilde{C}_2(0) + \gamma^{1/4}(n)\sqrt{\tilde{C}_2(0)[\gamma^{1/2}(n) - 2] + 2}}{\tilde{C}_2(0) - 1}, \tag{10}$$

where $\gamma(n)$ is defined in (5) and $\tilde{C}_2(0) \equiv C_2(0)/\xi(N)$. The upper limit of $C_2(0)$ depends on $\langle N \rangle$ and the quantum thermal features of BEC pattern given by $\gamma(n)$: $C_2(0) < \xi(N)[1 - \gamma^{1/2}(n)/2]^{-1}$. This upper limit is restricted by the maximal value of 2 in the ideal case as $\langle N \rangle \to \infty$ and $\gamma(n) = 1$.

Note, that for $C_2(Q)$ - function (4), the limit $\alpha \to \infty$ yields for fully coherent sources with small $\langle N \rangle$, while $\alpha \to 0$ case stands for fully chaotic (incoherent) sources as $\langle N \rangle \to \infty$. Actually, the increasing of T leads to squeezing of the domain of stochastic forces influence, and $L_{st}(T = T_0) = R$ at some effective temperature T_0. The higher temperatures, $T > T_0$, satisfy to more squeezing effect and at the critical temperature T_c the scale $L_{st}(T = T_c)$ takes its minimal value. Obviously, $T_c \sim O(200\, GeV)$ defines the phase transition where the chiral symmetry restoration

will occur. Since in this phase all the masses tend to zero and $\alpha \to 0$ at $T > T_c$, one should expect the sharp expansion of the region with $L_{st}(T > T_c) \to \infty$.

Using the relation between R_L and m_T obtained from the Heisenberg uncertainty relations [14] $R_L(m_T) = c\sqrt{h\, R_0/2\,\pi\, m_T}$ one can estimate R_0 within the formula:

$$R_0 \simeq \frac{2\,\pi}{c^2\,h}\left[\frac{\pi^2\,M_H^2}{3\,\zeta(3)\,\alpha(N)\,T_0^3\,m_T^4}\right]^{\frac{2}{5}}, \tag{11}$$

where c and h are the speed of light in vacuum and the Planck constant, respectively. The expression (11) relates the two-photon emission time R_0 with the Higgs-boson mass M_H, the transverse mass of two photons m_T and the temperature of the BEC domain $T_0 > n\,m_T$. From (11) one obtains $R_0 \simeq 10^{-24} sec$ and $R_0 \simeq 0.45 \cdot 10^{-24} sec$ for $T_0 = 50$ GeV and $T_0 = 100$ GeV, respectively, at $M_H = 120$ GeV and $m_T = 1$ GeV in the case of two final muon pairs. The confirmation of this should come from the measurement of the Higgs-boson lifetime in two-photon decay channel, as well as from the BEC data of electroweak interacting particles.

The qualitative relation between R and L_{st} above mentioned is the only one we can emphasize in order to explain the mass and temperature dependencies of the source size. The dependence of the stochastic measure of chaoticity α on the minimum scale cut L_{st} and Q_{rms} can be used to define the fit region for different p_T. Such a minimum cut on L_{st} introduces a lower cutoff on R.

There are a number of effects which may give rise to $Q \simeq 0$ correlations and, thus, mimic the two-photons BEC coming from Higgs decays. These include *i*) correlations of light hadrons and/or vector bosons misidentified as photons, *ii*) radiative decays of resonances in both pseudoscalar and vector sectors, *iii*) collective flow, etc.

Apparatus or analysis effects which may result in the sensitivity of external random forces influence, may be investigated by studying the dependence of the correlation functions on the stochastic scale L_{st}. This effect is expected to contribute strongly at small L_{st} (or large α and T).

Our model is consistent with the idea of the unification of weak and electromagnetic interactions at $T > T_c$, predicted by Kirzhnitz and Linde in 1972 [15,16]. In addition, there is the analogy with the asymptotic free theory: the properties of environment (media) are the same as those composed of free particles in the infinite volume (Universe).

5. **To summarize:** one of the main reasons to study BEC at finite temperature is the possibility to determine the precision with which the source size parameter and the strength chaoticity parameter(s) can be measured at particle colliders. Such investigations provide an opportunity for probing the temperature of the particle production source and the details of the external forces chaotic influence. Moreover,

one can predict the mass of the Higgs-boson. No systematic theoretical treatment of the Bose-Einstein effect within the Higgs decays in $\gamma^\star$ - pair production has been given so far.

In this paper, we faced to the model $C_2(Q,\beta)$ - function in which the contribution of N, T, α are presented. This differs from the methods used in, e.g., LEP experiments based on the approach (3). In fact, the latter resembles the traditional way of BEC study, however any qualitative interpretations of R, λ, ϵ have no been clarified. The model proposed in this paper is expected to be sensitive to the temperature of the environment and to the external distortion effects.

We find that the stochastic scale L_{st} decreases with increasing T slowly at low temperatures, and it decreases rather abruptly when the critical temperature is approached.

We obtain the dependence of the correlation strength functions λ_1 and λ_2 on the distance L_{st} and the maximal value of C_2 at minimum invariant momentum Q and T.

We predict for the first time the spatial size of the source (the correlation radius R) of two photons originated from the Higgs-boson decay in restricted domain at the proper temperature T_0. The dependence of the Higgs-boson mass, the mean multiplicity $\langle N\rangle$ and the lepton mass is obtained in the form

$$R \sim \frac{M_H^{2/5}\, e^{2\, m_l/5T_0}}{\alpha^{1/5}\langle N\rangle\, T_0^{3/10}\, m_l^{11/10}}$$

for low values of $T_0 < n\, m_l$, while for higher temperatures one has

$$R \sim \frac{M_H^{2/5}}{\alpha^{1/5}\langle N\rangle\, T_0^{3/5}\, m_l^{4/5}}.$$

The correlation radius R increases with heavier Higgs-bosons at large gamma-quantum mean multiplicity $\langle N\rangle$. Actually, the experimental measuring of R (in fm) can provide the precise estimation of the effective temperature T_0 which is one of the main thermal characters in the $\gamma^\star\gamma^\star$ pair emitter source in the proper leptonic decaying channel $\gamma^\star\gamma^\star \to l\bar{l}l\bar{l}$ with the final lepton energy $\sqrt{\vec{k}_l^2 + m_l^2}$ at given $\alpha(N)$ fixed by $C_2(Q=0)$ and $\langle N\rangle$. T_0 is the true temperature in the region of multiparticle production with dimension $R = L_{st}$, because at this temperature it is exactly the creation of two γ quanta occurred in decay of Higgs-boson, and these particles obey the criterion of BEC.

The parameter α can be extracted from the experimental data on the two-photon $\gamma^\star\gamma^\star$ BEC using $C_2(Q)$ with Q being close to zero (see (10)). This allows one

to estimate the Higgs-boson mass, M_H, at the temperature T_0. As a qualitative illustration we present here an estimation of M_H assuming $T_0 = 50, 100$ GeV, $\alpha = 10$ % and $m_l = m_\mu = 105$ MeV. The result is rather sensitive to the correlation radius R and T_0: $M_H = 167$ GeV at $T_0 = 50$ GeV, $M_H = 477$ GeV at $T_0 = 100$ GeV for $R = 1.0\ fm$; $M_H = 68$ GeV at $T_0 = 50$ GeV, $M_H = 194$ GeV at $T_0 = 100$ GeV for $R = 0.7\ fm$;

Because of the fact that $(\mu^+\mu^-)$ pairs originated from $\gamma^\star$ decay overlap in space and are created in time almost simultaneously, it is natural to expect that there are correlation between $(\mu^+\mu^-)$ pairs coming from different $\gamma^\star$'s due to Bose-Einstein interference. These effects may also affect the accuracy with which the $(\mu^+\mu^-)$ pair mass can be measured at the LHC.

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